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In situ identification of the failure mechanisms in self-reinforced poly(lactic acid) composites

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The growing public concern and new environmental legislations are driving forces for new materials with less environmental impact during the entire life cycle. As a result, biobased and biodegradable polymers have been extensively studied with Poly(lactic acid) (PLA) being one of the most promising biopolymer due to its attractive mechanical properties, the low amount of energy needed for production and its biodegradability [1]. Due to its brittleness, however, PLA is reinforced with fibres (e.g. natural fibres) to improve its mechanical and thermal properties [2]. Despite the use of natural fibres, there are issues with recycling of these composites. An alternative approach is the concept of “self-reinforced polymer” composites where the polymer matrix is reinforced with oriented fibres of the same polymer [3]. These materials are fully recyclable since there is no need to separate the fibres from the matrix.

In the present work, we produce highly oriented fibres from PLA pellets by extrusion followed by solid state drawing. The PLA matrix is also in the form of fibres but has a lower melting point. Commingling the two types of fibres, results in hybrid yarns that can be wound to produce unidirectional sheets (after consolidation) or woven into fabrics, which can be subsequently consolidated to sheets. The consolidation temperature is lower than the melting point of the highly oriented fibres, which will remain intact, but higher than the melting point of the low melting fibres. In this way, a self-reinforced PLA composite can be produced.

The stiffness of the self-reinforced PLA composites is significantly higher than the pure PLA material and competes with self-reinforced composites based on fossil hydrocarbon sourced polymers such as all-polypropylene composites. However, the strength of the self-reinforced PLA composites is still relatively low and needs to be improved.

For this reason, the tensile response of the self-reinforced PLA composites is characterised in situ in order to identify the failure mechanisms and more importantly the sequence of damage development (including load levels). The tests are performed inside the chamber of an environmental scanning electron microscope under vapour pressure mode to minimise charging of cracks upon loading. Based on the experimental results, suggestions are drawn for optimising the mechanical properties (strength) of the self-reinforced PLA composites i.e. combination of fibre, matrix and interface properties.

References

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